

## **REAL TIME IMAGING SYSTEM FOR CRANIOFACIAL RECONSTRUCTION: FROM GEOMATIC TO MEDICAL APPLICATIONS**

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### **Abstract**

*For medical purposes (such as craniofacial reconstruction), human faces and skulls (i.e. soft and hard tissues) need to be modeled and measured accurately. In Malaysia, many surgeons are still using the laborious traditional contact method (for example, calipers) for measuring anthropometric landmarks on human face. Consequently, a multi-disciplinary Prioritised Research (under IRPA) is established between Universiti Teknologi Malaysia (UTM), Standards & Industrial Research Institute Malaysia (SIRIM), and Universiti Sains Malaysia (USM). The research focuses on the development of surgical planning system for craniofacial reconstruction, for both the soft and hard tissues. The craniofacial reconstruction requires the following: imaging and measurement (non-contact, precise, rapid), 3D models (digital and physical), database, and surgical planner. This paper discusses the research works undertaken by UTM on the development of the imaging system (close range, non-contact, and real time) and information system (i.e. database) for craniofacial. The real time imaging system combines the laser scanning and photogrammetric techniques for acquiring high-resolution 3D models of craniofacial soft tissue. The information system integrates various inputs (soft tissue from laser scan and photogrammetry, hard tissue from CT-scan, measurement, patient's information, etc) for managing and visualizing the craniofacial data. Some actual results are shown to highlight the developed approach.*

### **1.0 INTRODUCTION**

Currently, the main measurement technologies include robotic total station, space-based Global Positioning System (GPS), digital photogrammetry, and laser scanning/tracking. Surveyors use these measurement technologies for geomatic applications, with the maps and plans as the main outputs. Nowadays, many applications (such as engineering, construction, industrial, medical, etc) require dimensional measurement (with precision ranging from cm to microns) and the results in the form of 3D computer models.

Medical applications (such as craniofacial reconstruction surgery) need precise measurement (and 3D modeling) of human faces (or soft tissue) and skulls (or hard tissue) (Figure 1). Our preliminary research indicated that most surgeons (in Malaysia) are still relying on laborious traditional contact method (for example, calipers) for measuring anthropometric landmarks on human face (Halim *et al*, 2004). Moreover, special automated measurement techniques are needed (i.e. non-contact, eye safe, fast, precise) for craniofacial application.



Figure 1. Human face and measurement

Since 2002, a multi-disciplinary Prioritised Research (under IRPA) is established between Universiti Teknologi Malaysia (UTM), Standards & Industrial Research Institute Malaysia (SIRIM), and Universiti Sains Malaysia (USM). The research focuses on the development of surgical planning system for craniofacial reconstruction, for both the soft and hard tissues. The craniofacial reconstruction requires the following: imaging and measurement (of soft and hard tissues), 3D models (digital and physical), database, and surgical planner.

## **2.0 METHOD**

In this research, the following imaging sensors are used: laser (and photogrammetry) and CT scan for capturing the soft and hard tissues respectively.

This paper discusses the research works undertaken by UTM on the development of the imaging system (close range, non-contact, and real time) and information system (i.e. database) for craniofacial. The real time imaging system combines the laser scanning (Mohd Sharuddin et al, 2005) and stereo photogrammetric techniques (M. Farid et al, 2005) for acquiring high-resolution 3D models of craniofacial soft tissue (Figure 2). The combination of laser (i.e. VIVID910) and photogrammetry provide rapid 3D model (via laser scanning) and precise landmark measurement (via photogrammetric) of the soft tissue.



Figure 2. The real time imaging system

All the data (from laser, photogrammetry and CT scan) are processed separately (Figure 3) using specialized software (i.e. RAPIDFORM, DVP, 3DSLICER), to generate inputs for the information system (i.e. 3D models and measurement of landmarks).

The information system is developed in-house (Deni et al, 2005), and integrates various inputs (soft tissue from laser scan and photogrammetry, hard tissue from CT-scan, measurement, patient's information, digital dental cast, etc) for managing and visualizing the craniofacial data (Figure 3).

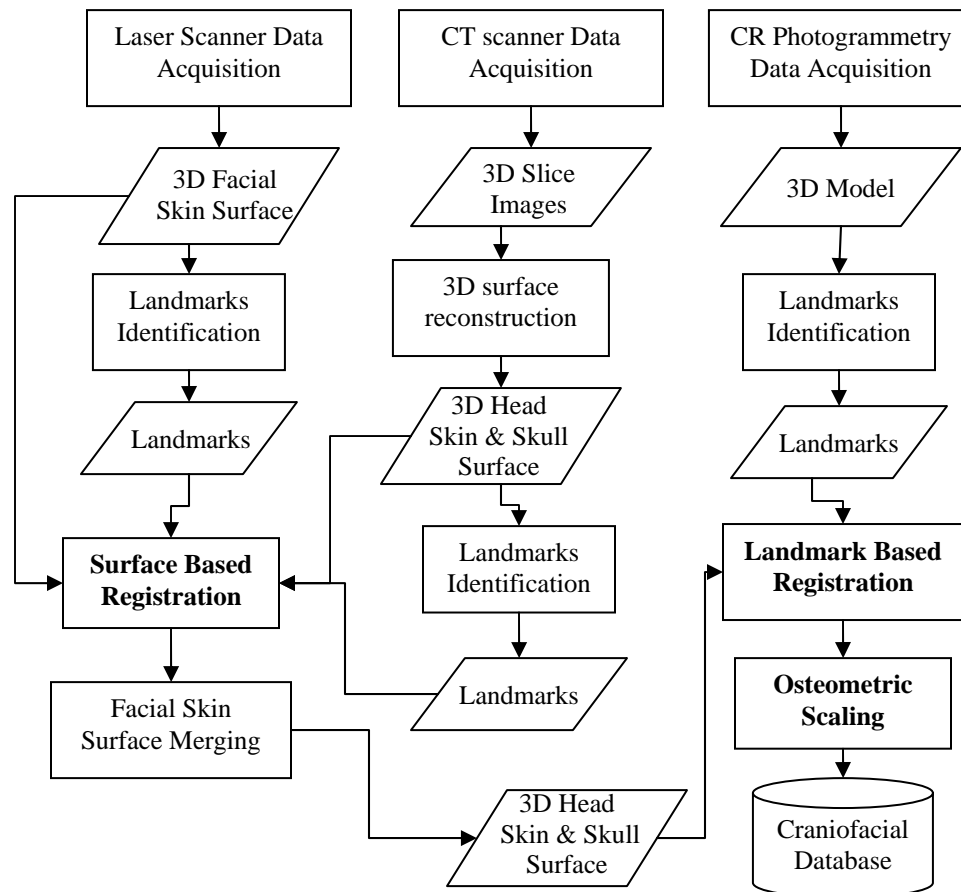


Figure 3. Data integration and craniofacial database

The interdisciplinary research team at UTM also concentrates on the following: 3D facial reconstruction (Abbas et al, 2005), cephalometric analysis (Ruzaini et al, 2005), facial morphology analysis (Zie Zie Azeanty et al, 2005), 3D surface measurement (Tan et al, 2005), statistical shape analysis (Mohd Bakery et al, 2005), database for craniofacial hard tissue (Zakiah et al, 2005), and modeling of soft tissue (Mohammad Azam et al, 2005).

### 3.0 RESULTS

Comparisons of between caliper, photogrammetry and laser are summarized in Table 1. Figure 4 shows an integrated 3D model by combining data from CT (i.e. skull), laser (i.e. face) and photogrammetry (landmarks). The information system (Figure 5) has the capability to perform 3 tasks, i.e. database, generating 3D model and measurement. To date, web-based system is under development (Deni Suwardhi, 2005).

Table 1. Comparison of results

Measurement Points	Calipers [A] +/- 0.05 (mm)	Photo [B] (mm)	Laser [C] (mm)	Diff 1 [B-A] (mm)	Diff 2 [C-A] (mm)	Diff 3 [C-B] (mm)
1 ~ 2	96.55	98.26	97.43	1.71	0.88	-0.83
6 ~ 7	60.25	58.68	57.08	-1.57	-3.17	-1.60
10 ~ 11	62.65	63.64	63.50	0.99	0.85	-0.14
4 ~ 3	63.90	61.04	65.94	-2.86	2.04	4.90
3 ~ 9	43.10	41.05	44.05	-2.05	0.95	3.00
1 ~ 3	56.70	54.96	58.52	-1.74	1.82	3.56
2 ~ 3	55.40	54.32	55.88	-1.08	0.48	1.56
10 ~ 3	45.30	44.40	46.40	-0.90	1.10	2.00
11 ~ 3	42.95	41.92	42.15	-1.03	-0.80	0.23
9 ~ 5	20.90	19.80	20.98	-1.10	0.08	1.18

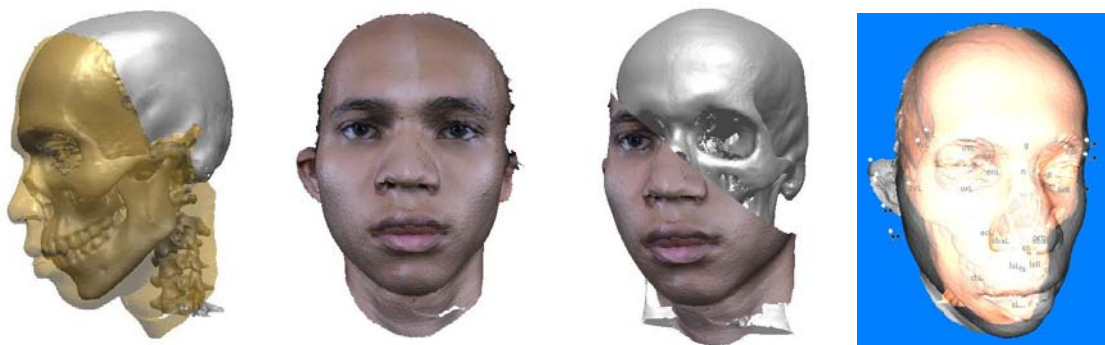


Figure 4. Integrated 3D model (Deni et al, 2005a)

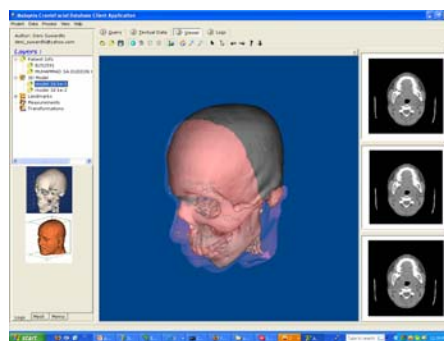


Figure 5. Craniofacial information system and database

#### 4.0 CONCLUSION

This paper focuses on the development of the imaging and information systems for craniofacial reconstruction. The results indicate the suitability of the adopted procedure for practical applications.

## **ACKNOWLEDGEMENT**

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